To determine the diagnostic accuracy of cardiokymography, recorded 2 to 3 minutes after exercise, 617 patients undergoing cardiac catheterization were evaluated from 12 participating centers using a standardized protocol. Adequate cardiokymographic tracings, which were obtained in 82% of patients, were dependent on the skill of the operator and on certain patient characteristics. Of the 327 patients without prior myocardial infarction who had technically adequate cardiokymographic and electrocardiographic tracings, 166 (51%) had coronary disease. Both the sensitivity and specificity of cardiokymography (71 and 88%, respectively) were significantly greater than the values for the exercise electrocardiogram (61 and 76%, respectively, both p < 0.01). Coronary artery disease and multivessel disease were present in 98 and 68%, respectively, of the 70 patients with concordantly positive cardiokymographic and electrocardiographic results, and in 15 and 5%, respectively, of the 132 patients with concordantly negative test results (p < 0.001).

Cardiokymography was most helpful in those patients in whom the posttest probability of coronary disease was between 21 and 72% after exercise electrocardiography. In these patients a concordantly positive cardiokymographic result increased the probability of coronary disease to between 67 and 100%, whereas a negative response decreased it to between 12 and 15%. In the subgroup of 102 patients undergoing concomitant exercise thallium testing, the sensitivity and specificity for the thallium scintigraphy (81 and 80%, respectively) were similar to the values for cardiokymography (72 and 84%, respectively; differences not significant). Thus, cardiokymography performed during exercise testing improves the diagnostic accuracy of the electrocardiographic response and provides an additional and cost-effective indicator of myocardial ischemia.

Cardiokymography has been used in conjunction with the standard exercise test as an additional marker of myocardial ischemia (3–5), and has been shown experimentally (6–8) to accurately detect regional wall motion by recording tissue movement through changes in an electromagnetic field. Results from these three independent clinical trials (3–5) suggest that the sensitivity and specificity of cardiokymography were higher than the values found for the exercise electrocardiogram and as good as the results obtained by exercise thallium scintigraphy (5). Questions about the accuracy, reliability and applicability of cardiokymography still remain because of the small number of patients previously studied and the different protocols used. We therefore sought to further evaluate the diagnostic accuracy and usefulness of cardiokymography during exercise testing in a multicenter trial using a standard protocol involving 617 patients.

**Methods**

**Patient population and protocol.** Between January 1983 and June 1984, 617 patients (420 men and 197 women) with an average age of 52.3 ± 5.2 years without prior...
cardiac surgery were enrolled in the study. Each patient was referred to 1 of the 12 participating institutions for cardiac catheterization because of suggested or known coronary artery disease. The participating institutions were chosen because they supported clinically oriented exercise laboratories in teaching or community hospitals. The three medical centers that had completed the initial evaluation of exercise cardiokymography (3–5) were specifically excluded from participation. For inclusion into the study, the patients were required to undergo exercise testing within 1 month of the cardiac catheterization. The decision to perform cardiac catheterization was made by the physicians caring for the patient and was not influenced by the results of cardiokymography, which was performed in conjunction with an exercise test.

The results of a clinical and demographic profile, the exercise electrocardiographic and cardiokymographic responses, the thallium scintigraphic findings (when available) and the catheterization data were recorded on standardized forms and sent to the coordinating center. Of the 617 patients, 29% had had a prior myocardial infarction. The chest pain complaints of the patients were categorized into one of three groups before catheterization: typical angina (42%), atypical angina (34%) and nonischemic chest pain (13%). Eleven percent of the patients were asymptomatic after a myocardial infarction. Three hundred thirty-four patients (54%) were taking a beta-receptor blocker, 136 patients (22%) were receiving a calcium antagonist and 8 patients (1%) were taking a digitalis preparation.

**Exercise test.** Each patient performed a progressive, symptom-limited, maximal treadmill exercise test according to the standard Bruce protocol (9). A 12 lead electrocardiogram and blood pressure were recorded at rest and during each stage of exercise and recovery. An abnormal electrocardiographic response was defined as the appearance of 1 mm of horizontal or downsloping ST segment depression or 1.5 mm of upsloping ST segment depression 80 ms after the J point for three consecutive beats during exercise or recovery compared with the baseline upright tracing. If the electrocardiogram at rest showed ST segment depression, an additional 1 mm of depression was required. Six patients showed left ventricular hypertrophy on their electrocardiogram at rest and two had left bundle branch block. All electrocardiographic tracings were interpreted independently at the participating site and coordinating site without knowledge of the results of either the exercise cardiokymogram or cardiac catheterization.

**Cardiokymography.** Cardiokymographic recordings were obtained in each patient at rest and during recovery from exercise using a commercially available cardiokymographic system (series 8000, Cardiokinetics). The cardiokymograph consists of two components: a probe and a signal-conditioning unit. A complete description of this device can be found in prior reports (6–8, 10–12). The probe is a 5 cm circular, flat capacitive plate, which is part of a high frequency (10 MHz) but low power (10 mW) oscillator. The plate is mounted in a plastic ring and strapped to the chest. The plate never touches the chest wall. Activation of the plate by battery current causes it to emit a low-energy electromagnetic field. This field is capable of penetrating air and underlying tissue without causing distortion of the underlying tissue motions. Tissue motion beneath the plate distorts the induced electromagnetic field producing a change in the probe’s effective capacitance, which, in turn, alters the frequency of an external oscillator. The signal processing unit then converts the change in oscillator frequency to a change in voltage proportional to the original motion. The change in voltage is then amplified and displayed on a multichannel recorder as a continuous analog signal. The frequency response of the system is flat ± 10% from 0.1 to 90 Hz (12). Signal output falls off rapidly as a function of distance (11, 12), and because the distance between the probe and the epicardial surface of the heart varies from patient to patient, the cardiokymographic waveform cannot be calibrated in terms of absolute motion. Despite this quantitative limitation, the cardiokymograph is capable of accurately representing the qualitative pattern of left ventricular wall motion (7, 10).

Cardiokymographic recordings were obtained at rest in the supine position at voluntarily held end-expiration. A simultaneously recorded transthoracic electrocardiographic lead was obtained at a paper speed of 50 mm/s. The optimal position for the most normal appearing baseline cardiokymographic recording was sought by moving the probe along the electrocardiographic precordial lead positions V2 to V5 (usually V3). The transducer position was marked on the chest, and the cardiokymographic probe was removed. Within 2 to 3 minutes after cessation of exercise, a cardiokymographic recording was again obtained in the previously marked baseline position at end-expiration and again 5 to 15 minutes into the recovery period.

The interpretation of the cardiokymographic tracings has been described previously in detail (3–5). In brief, the tracings were classified according to three patterns: types I, II and III (see Fig. I for details). All normal configurations were type I. Abnormal configurations were type II or III responses. The cardiokymographic tracings were considered abnormal only if a type I motion at rest became type II or III after exercise. The cardiokymographic tracings were considered inadequate for interpretation either if the baseline tracing at rest was not type I or if the postexercise tracing could not be placed into any of the three patterns.

The cardiokymographic tracings were interpreted independently by investigators at the participating and coordinating sites, without prior knowledge of the results of the exercise electrocardiogram or cardiac catheterization or each other’s cardiokymographic interpretation.

**Exercise thallium scintigraphy.** Although exercise thallium scintigraphy was not required for inclusion in the protocol, these results were recorded on standardized forms
when available. Exercise thallium testing was performed according to the usual protocol at each institution. A percutaneous indwelling catheter was inserted into a vein before exercise. Approximately 2 mCi of thallium-201 chloride was injected into the catheter within 1 minute before cessation of exercise. Within 5 minutes after terminating exercise, imaging was begun. Three or four views were obtained in the anterior, 45° left anterior oblique, 60° left anterior oblique and left lateral positions. Redistribution images were obtained 3 to 4 hours after exercise.

Coronary arteriography. Selective coronary arteriograms using the brachial or femoral techniques were recorded in multiple projections according to the standard practice at each institution. Significant coronary artery disease was judged present if a 50% or greater reduction in vessel diameter occurred in the left main coronary artery or a 70% or greater narrowing was present in at least one of the other major arterial segments. Of the 617 patients, 38% had no significant coronary disease. One, two and three vessel coronary disease was found in 173 patients (28%), 123 patients (20%) and 86 patients (14%), respectively.

Data analysis. The total group of 617 patients was analyzed for the adequacy of the cardiokymographic tracings and the interobserver variability of interpretations. For the comparison of the diagnostic accuracy of cardiokymography with that of exercise electrocardiography and thallium scintigraphy, a subgroup of 327 patients was evaluated. This subgroup included only those patients without a prior myocardial infarction in whom both the exercise electrocardiographic and the cardiokymographic tracings were interpretable. These patients also achieved a peak exercise heart rate of at least 85% of the age-predicted maximal heart rate when both the electrocardiographic and cardiokymographic results were negative.

All analyses of data were performed using chi-square analysis for categorical variables and t testing for quantitative variables. Probabilities were considered significant at the 0.05 level.

Results

Adequacy of tracings. Technically adequate cardiokymographic tracings were obtained in 82% of the 617 patients. Among the 109 inadequate tracings, 85 were uninterpretable at rest and 24 after exercise. A prior myocardial infarction was the only distinguishing characteristic between patients with and without adequate tracings (25 versus 60%, respectively, p < 0.001). The exercise electrocardiogram was not interpretable in 26 patients (4%).

Interobserver variability. Disagreements in the interpretations between the readers at the participating site and the coordinating center occurred among 11% of the electrocardiographic tracings and among 12% of the cardiokymographic tracings. The discordant interpretations were resolved by group review at the coordinating center.

Sensitivity and specificity. Among the subgroup of 327 patients without prior myocardial infarction and with adequate interpretable tracings, 166 (51%) had significant coronary artery disease. The cardiokymogram was abnormal in 118 patients, whereas the exercise electrocardiogram was abnormal in 102 patients (sensitivities of 71 and 61%, respectively, p < 0.01). One hundred sixty-one patients (49%) had no significant coronary disease. The cardiokymogram was negative in 141 patients and the exercise electrocardiogram in 122 patients (specificities of 88 and 76%, respectively, p < 0.01). The prevalence of coronary disease and the sensitivity and specificity of the cardiokymogram and electrocardiogram varied widely depending on the description of the patient's chest pain and the sex of the patient (Table 1).

Extent of coronary artery disease. The cardiokymogram and electrocardiogram were abnormal in 59 and 44%, respectively, of the 70 patients with one vessel coronary artery disease, in 75 and 66%, respectively, of the 55 patients with two vessel coronary disease and in 88 and 85%, respectively, of the 41 patients with three vessel coronary disease. Among the 70 patients with one vessel disease, the cardiokymogram was abnormal in 72% of the 39 patients with left anterior descending artery disease, in 50% of the 8 patients with left circumflex artery disease and in 39% of the 23 patients with right coronary artery disease.

Analysis of the combined test results (Fig. 2). Two hundred seventeen patients (66%) had concordant test results for the cardiokymogram and electrocardiogram (85 positive and 132 negative). Coronary artery disease and multivessel disease were present in 92 and 68%, respectively, of the patients with concordantly positive results, compared with 15 and 5%, respectively, of the patients with concordantly negative results (p < 0.001). When the cardiokymographic and electrocardiographic results were dis-
Table 1. Sensitivity and Specificity of Clinical History, Exercise Electrocardiographic Responses and Cardiokymographic Results Among the 327 Patients Without Prior Myocardial Infarction

<table>
<thead>
<tr>
<th>Prevalence*</th>
<th>ECG*</th>
<th>CKG*</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>CAD</td>
<td>MVD</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical angina (n = 85)</td>
<td>85 ± 4</td>
<td>51 ± 5</td>
</tr>
<tr>
<td>Atypical angina (n = 96)</td>
<td>51 ± 5</td>
<td>26 ± 5</td>
</tr>
<tr>
<td>Nonischemic pain (n = 28)</td>
<td>25 ± 8</td>
<td>7 ± 5</td>
</tr>
<tr>
<td>Asymptomatic (n = 9)</td>
<td>33 ± 16</td>
<td>22 ± 14</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical angina (n = 33)</td>
<td>46 ± 9</td>
<td>30 ± 8</td>
</tr>
<tr>
<td>Atypical angina (n = 54)</td>
<td>33 ± 6</td>
<td>13 ± 5</td>
</tr>
<tr>
<td>Nonischemic pain (n = 17)</td>
<td>23 ± 10</td>
<td>6 ± 6</td>
</tr>
<tr>
<td>Asymptomatic (n = 5)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Expressed as percentages ± 1 standard error of the percent. CAD = coronary artery disease; CKG = cardiokymography; ECG = electrocardiography; MVD = multivessel coronary artery disease; n = number of patients.

cordant, the predictive accuracy of a positive cardiokymographic response for coronary disease was significantly higher than that of a positive electrocardiographic result (74 versus 43%, respectively, p < 0.001).

To determine which subgroup of patients derive the most benefit from cardiokymographic stress testing, we categorized the chest pain complaints of the 327 patients undergoing testing for the purpose of diagnosis into four symptom groups: typical angina (35%), atypical angina (46%), nonischemic chest pain (15%) and asymptomatic (4%). The prevalence of coronary disease ranged from 0 to 85% on the basis of the sex and symptom group (Table 1). By inference, these prevalence values represent disease probabilities for individual patients.

**Typical angina.** A history of typical angina pectoris in men was very predictive of both coronary artery disease (85%) and multivessel disease (51%). A positive exercise electrocardiographic response increased the probability of coronary disease to 94% (Fig. 3). In these patients, a positive cardiokymographic response only slightly increased the probability of coronary disease (to 95%), whereas a negative cardiokymogram was still associated with a high probability

Figure 2. Correlation between the combined stress test cardiokymographic (CKG) and electrocardiographic (ECG) results and the presence of coronary artery disease (CAD) and multivessel disease among the subgroup of 327 patients without prior myocardial infarction.

Figure 3. Correlations among the electrocardiographic (ECG) and cardiokymographic (CKG) responses to exercise and coronary angiography in men and women with typical angina. CAD = coronary artery disease.
of coronary disease (93%). A negative electrocardiographic response in men with typical angina was associated with a 68% probability of coronary disease. In these patients, a positive cardiokymographic response substantially increased the probability of coronary disease to 94%, while a negative response decreased it to 40%. In women, only 46% of those with a history of typical angina had coronary disease and 30% had multivessel disease. A positive exercise electrocardiographic response increased the probability of coronary disease to 78% (Fig. 3). In these women, a positive cardiokymographic response was associated with a 92% probability of coronary disease, while a negative response lowered the probability to 40%.

**Atypical angina.** In the atypical angina group, 51% of the men and 33% of the women had coronary artery disease (Table I). A positive exercise electrocardiographic response increased the probability of coronary disease to 72% in the men and to 53% of the women (Fig. 4). In these patients, a positive cardiokymographic response increased the probability of coronary disease to 90% in men and to 86% in women, while a negative result was associated with a probability of 27% in men and 25% in women (Fig. 4). A negative electrocardiographic response in patients with atypical angina was still associated with a 37% probability of coronary disease in men and a 20% probability in women. In these patients, when the cardiokymographic response was negative, the probability of coronary disease (15% in men and 12% in women) and of multivessel disease (5% in men and 3% in women) was very low.

**Nonischemic chest pain.** We combined the male and female patients with nonischemic chest pain into a single group because of their smaller sample size. In this combined group of 43 patients, 24% had coronary disease and 7% had multivessel disease. A positive electrocardiographic response resulted in a 43% probability of coronary disease, while a negative electrocardiographic result was associated with a 17% probability (Fig. 5). In the 14 patients with positive exercise electrocardiographic responses, a positive cardiokymographic response increased the probability of coronary disease to 80%, whereas in the 30 patients with negative electrocardiographic results, a negative cardiokymographic response, which was present in 26 patients, lowered the probability to 8%. No patient had multivessel disease (Fig. 5).

**Thallium scintigraphy versus exercise electrocardiography and cardiokymography.** In the subgroup of 102 patients having combined exercise electrocardiography, cardiokymography and thallium scintigraphy, 58 patients (57%) had coronary artery disease. The sensitivity of thallium scintigraphy was higher than that for exercise electrocardiography (81 versus 65%, p < 0.05) but was similar to that for cardiokymography (81 versus 72%, difference not significant). The specificities of all three noninvasive tests were similar (Table 2). Thirty-nine patients had one vessel coronary artery disease. In this group, cardiokymogram and thallium scintigraphic results were abnormal in 67 and 74%, respectively, of the 27 patients with left anterior descending disease; and in 42 and 50%, respectively, of the 12 patients with either left circumflex (3 patients) or right (9 patients) coronary artery disease. Among the 42 of the 58 patients with coronary artery disease with abnormal cardiokymographic results, thallium scintigraphy showed the following findings: posteroinferior ischemia in 3 (7%), anterior or

![Figure 4](image-url)  
**Figure 4.** Correlations among the electrocardiographic (ECG) and cardiokymographic (CKG) responses to exercise and coronary angiography in men and women with atypical angina. CAD = coronary artery disease.

![Figure 5](image-url)  
**Figure 5.** Correlations among the electrocardiographic (ECG) and cardiokymographic (CKG) responses to exercise and coronary angiography in patients with nonischemic chest pain. CAD = coronary artery disease.

<table>
<thead>
<tr>
<th>Table 2. Sensitivity and Specificity of Exercise Tests in the Subgroup of 102 Patients Undergoing Combined Testing</th>
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<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td>Electrocardiography</td>
</tr>
<tr>
<td>Cardiokymography</td>
</tr>
<tr>
<td>Thallium scintigraphy</td>
</tr>
</tbody>
</table>

*Expressed as percent ± 1 standard error of the percent.
septal ischemia in 13 (31%), multiple defects in 21 (50%) and no defect in 5 (12%). When exercise electrocardiography and cardiokymography were both positive, the predictive accuracy for detecting coronary disease (91%) was similar to that for positive exercise electrocardiography and thallium scintigraphy (89%). The absence of coronary disease was found in 77% of patients with concordantly negative exercise electrocardiographic and cardiokymographic responses and in 78% of patients with combined negative electrocardiographic and thallium scintigraphic responses.

Discussion

To aid in the detection of coronary artery disease, the clinician may choose among many noninvasive tests, including the standard exercise test, cardiac fluoroscopy and exercise radioisotopic techniques, such as thallium-201 perfusion scintigraphy or radionuclide angiography. All these techniques when evaluated alone have diagnostic limitations because of poor sensitivity or specificity in different patient groups (13). The combined use of two or more of these procedures has been reported to provide a more accurate detection of coronary disease (14). The rationale for a multiple test approach is related to the theory that, although the predictive accuracy of any of these tests may be quite low in a given patient, the accuracy of two or more independent tests is very high if all results are concordant (13). Limitations of the use of the multiple diagnostic test approach include the higher cost involved, increased risk of radiation when radionuclide techniques are utilized and continued uncertainty when discordant responses occur (15).

This multicenter trial was designed to evaluate more thoroughly the diagnostic accuracy of a new noninvasive device using a standardized protocol during exercise testing before the widespread proliferation of this technology. The participating sites chosen for the trial represented a combination of both community and academic hospitals geographically distributed throughout the United States and Canada.

Comparison with prior studies. The findings of this trial confirm the results of three independent studies (3–5) that cardiokymography after exercise is a useful technique for detecting myocardial ischemia. It was most helpful in identifying patients with three vessel coronary disease, especially those with left anterior descending coronary artery disease causing anterior ischemia. The sensitivity and specificity of cardiokymography were higher than the values for exercise electrocardiography and comparable with those of exercise thallium scintigraphy in the subgroup of patients undergoing all three evaluations. One previous investigation (5) also found that the diagnostic accuracy of cardiokymography after exercise was similar to that for thallium scintigraphy. It is important to emphasize that the patients in the present trial were not referred for cardiac catheterization because of the cardiokymographic results. It is likely, however, that an abnormal exercise electrocardiographic or thallium scintigraphic response did influence the decision to perform catheterization. If so, this bias would serve to lower the observed specificity of the test results in this study (16).

Combined test results. Different manifestations of myocardial ischemia during exercise may occur, resulting in either electrocardiographic or regional wall motion abnormalities. According to Bayes’ theorem, when two independent tests produce concordant responses, their combined analysis should enhance overall diagnostic accuracy (13,17,18). Sixty-six percent of the patients displayed concordant test responses. Combined positive exercise electrocardiographic and cardiokymographic responses were associated with a high probability of coronary disease (92%) and multivessel disease (68%), whereas concordantly negative test results resulted in a low probability of coronary disease (15%) and multivessel disease (5%). In the remaining one-third of patients with discordant test responses, the probability of coronary disease was intermediate (59%). In these patients, exercise thallium scintigraphy would be helpful.

Value of cardiokymography in subgroups of patients. Our analysis identified certain clinical subsets of patients in which cardiokymography performed during exercise testing was especially helpful. Men with atypical angina or nonischemic chest pain and women with typical or atypical angina had pretest probabilities of coronary artery disease ranging from 25 to 51% before exercise testing. In these patients, the results of exercise electrocardiographic testing alone still resulted in diagnostic uncertainty because the posttest probability of coronary disease ranged from 30 to 72% with a positive electrocardiographic response and from 21 to 37% with a negative response. A concordantly positive cardiokymographic response increased the posttest probability of coronary disease to between 67 and 100%, while a concordantly negative cardiokymographic result decreased it to between 12 and 15%. However, patients with either a high pretest probability of coronary disease, such as men with typical angina, or a low pretest probability, such as asymptomatic patients or women with nonischemic chest pain, usually have a correspondingly very high or very low posttest probability after a standard exercise test. Another noninvasive test such as cardiokymography would be helpful only when an unexpectedly positive or negative electrocardiographic response occurs. Finally, cardiokymography may also be useful in patients whose exercise electrocardiographic response is potentially uninterpretable, as with patients taking a digitalis preparation or those whose baseline electrocardiogram demonstrates left bundle branch block or left ventricular hypertrophy (3).

Variability of interpretations and inadequate tracings. The interobserver variability for cardiokymographic interpretation was similar to that for electrocardiographic interpretation and for the variability reported for visual inter-
interpretation of thallium scintigrams (19–21). The adequacy of the cardiokymographic tracings was dependent on the experience and patience of the operator and on certain patient characteristics. Inadequate baseline cardiokymographic tracings, precluding interpretation of the exercise recording, were frequently found in patients with prior myocardial infarction whose cardiokymogram at rest often demonstrates a paradoxical outward systolic motion. Patients with a prior myocardial infarction ordinarily do not undergo testing for the purpose of anatomic diagnosis. Accordingly, if these patients had been excluded from analysis, only 8% of the cardiokymographic tracings would have been uninterpretable.

**Potential limitations.** First, our patient group was selected because they were referred for cardiac catheterization. Thus, our conclusions might not be applicable to other symptomatic or asymptomatic patients not undergoing catheterization whose pretest probability of coronary disease would be expected to be lower. Second, we did not apply multivariate analysis to exercise testing, an approach that has been useful in predicting the extent of coronary disease and the prognosis of patients (22,23). Finally, we did not use quantitative analysis of thallium images. It is likely that this technique would have enhanced the sensitivity and specificity of exercise thallium scintigraphy (24–26). Although the cardiokymogram cannot yet be computer-enhanced or analyzed quantitatively, it does possess certain desirable characteristics, such as the lack of an intravenous catheter and radiation exposure and the lower cost and shorter amount of time required to perform this procedure.

**Conclusions.** The results of this multicenter trial confirm the use of cardiokymography after exercise as a useful noninvasive technique for the detection of coronary disease. The combined use of cardiokymography with a standard exercise test can improve the diagnostic accuracy of exercise electrocardiography alone, especially in the patients with an intermediate pretest probability of coronary disease. When the combined results are concordantly positive or negative (as they were in two-thirds of our patients), the posttest probability of coronary disease is usually high or low enough to obviate the need to perform additional testing. Exercise radionuclide tests could be targeted in a more cost-effective manner to the remaining patients with discordant test responses.

**Study Participants**

**Clinical Units**

- **Jewish Hospital, St. Louis, MO.** Principal Investigators: Ronald J. Krone, MD, Keith Fischer, MD; Data Coordinator: Gail Eisenkremer, RN.
- **Creighton University School of Medicine, Omaha, NB.** Principal Investigators: Michael H. Skechta, MD, Mark A. Williams, PhD; Data Coordinator: Valerie Beverland.
- **University of Medicine and Dentistry, Newark, NJ.** Principal Investigator: S. Sultan Ahmed, MD; Data Coordinator: Martha Thomas, RN.
- **The Heart Institute for C.A.R.E., P.A., Amarillo, TX.** Principal Investigator: Robert E. Guidle, MD; Data Coordinator: Les Swafford, PA.
- **University of Ottawa Heart Institute, Ottawa, Ontario.** Principal Investigator: Michael G. Baird, MD; Data Coordinator: Habib Habibi, MD.
- **University of Minnesota Hospitals, Minneapolis, MN.** Principal Investigator: Jay N. Cohn, MD; Data Coordinator: Marcus Mianulli.
- **Montreal Heart Institute, Montreal, Quebec.** Principal Investigator: Bernard R. Chaitman, MD (currently at St. Louis University); Data Coordinator: Ruth Nelson.
- **University of Alabama, Birmingham, AL.** Principal Investigator: L. Thomas Sheffield, MD; Data Coordinator: Octavia Storey.
- **University of New Mexico, Albuquerque, NM.** Principal Investigator: Jonathan Abrams, MD; Data Coordinators: Carolyn Benson, Janine Moss.
- **Long Beach Memorial Hospital, Long Beach, CA.** Principal Investigators: Myrvyn H. Ellesdorad, MD, Peiliang Kuan, MD; Data Coordinator: LaVergne Thomas.
- **Stanford Medical Center, Palo Alto, CA.** Principal Investigator: Robert F. DeBusk, MD; Data Coordinator: Dale Mayer, RN.
- **University of California at Davis, Sacramento, CA.** Principal Investigators: Lawrence J. Laslett, MD, Ezra A. Amsterdam, MD; Data Coordinator: Linda Paumer.
- **Consulting Center**
  - ** Cedars-Sinai Medical Center, Los Angeles, CA.** George A. Diamond, MD.
- **Clinical and Data Coordinating Center**
  - **Boston University Medical Center, Boston, MA.** Principal Investigator: Donald A. Weiner, MD; Project Coordinator: Carolyn H. McCabe, BS; Data Coordinator: Sally S. Cutler, BS; Secretary: Mary-Grace L ett.

**References**


